To: Walter M. Scott, Assistant Chief, BAIC July 29, 1952

From: Robert E. Stevenson, Technical Advisor, BAIC

Subject: Soil Conditioners - Opportunities for Research in BAIC

Purpose: The purpose of this report is to analyze current thinking on the present and future commercial possibilities of soil conditioning chemicals to determine the soundest basis on which to initiate research in BAIC in this field, if it is decided to do so.

I have attempted in this report to cover the following:

1. Background of need for soil conditioners
2. Industrial developments
3. Problems visualized in establishing stable mass market for chemical soil conditioners
4. Approaches for research on soil conditioners in BAIC

Summary: Soil scientists in the Department whom I interviewed are in general agreement that there is a real need for inert, stable soil conditioners, especially for reclaiming soils which are alkaline, saline, sandy or high in clay content.

Industrial developments within the past several years have indicated that polyacrylates, polyacrylonitriles, maleic acid derivatives and various other compounds are effective chemical soil aggregants. Maximum formation of water-stable soil aggregates appears to be reached with products studied so far when approximately a ton of active ingredient is applied per acre at a six-inch soil depth. Application at about this depth appears necessary for general farm use to avoid re-application from year to year. Not all of the products recently announced as soil conditioners are equally effective, although the best of them, such as Monsanto's Kriliums and American Cyanamid's Aerotils, do appear to be living up to advance claims for improving certain soils deficient in texture and structure. These conditioners are most effective on soils with high clay and silt content, but are not effective on very sandy soils. Naturally, soils of good structure initially do not show great improvement.

It is believed that a really large, stable market for soil conditioning chemicals will not develop until such products are reduced in cost to a level to make their use profitable in large-scale farming operations. The present boom in soil conditioners represents a response to a new fad, and even at 50% lower prices it is expected that such conditioners would probably settle down to usage in greenhouses, specialty farms and hobby gardens. Even these markets might diminish, since at least one of the products widely distributed in the East is regarded as worse than useless

and unfavorable reaction is sure to follow. Regardless of the eventual outcome, the publicity given soil conditioners has probably made a definite contribution to modern soil management in arousing increased awareness of the importance of soil structure in relation to germination and plant growth. Time will tell whether the benefits of chemical soil aggregants are worth their cost in terms of their net effects upon soils and crops.

Regarding approaches for research in BAIC to develop acceptable, low-cost soil conditioners, opportunities exist technically, although questionable economically, for successful chemical modification of wastes and residues. Such opportunities would appear brightest economically for utilization of those wastes which pose least problems of collection, transportation and storage. At least two firms have already been established which are marketing composts presumably derived from agricultural wastes. It is believed our prospects would be better if we concentrate upon developing inert, stable derivatives functioning in the same manner as Krilium but having pronounced cost advantages. In view of the present competition in this field, it is logical to assume that the utilization of residues is not being overlooked, and that chemical manufacturers will be quick to take advantage of any findings which demonstrate their economic use.

Acknowledgment:

This information represents an amalgamation of facts, opinions, and impressions gleaned from (1) recent memoranda furnished by the Regional Laboratories, (2) published and unpublished reports on the subject, and (3) consultation with Drs. R. Q. Parks and M. S. Anderson of BPISAE and Drs. R. D. Hockensmith and C. S. Slater of SCS. These soil scientists are members of the Department "Committee on Soil Conditioners," organized to coordinate research in this field being conducted by various agencies within Agriculture, principally BPISAE, SCS, and OES. They were most cooperative in presenting their views on the subject. Research suggestions in Part 4 were furnished in response to Dr. Scott's memorandum of February 20, 1952, by staff members of the Regional Laboratories as indicated.

Details: (1) Background of need for chemical soil conditioners (soil experts prefer the term "chemical soil aggregants").

Beneficial use can be made of soil conditioners in two distinct but related applications, (a) to maintain soil productivity and (b) to control soil erosion. I was unable to obtain information showing acreage of soils and crops which stand to gain through use of conditioners.

(a) To maintain soil productivity: There is a tremendous variation in soil texture (proportion of sand, silt and clay) and in structure (arrangement of primary particles into aggregates with varying stability to water). Most rich, loamy soils are

generally productive, whereas hard, tight, clay-packed soils are not, even though the soils may be very similar chemically. Productivity drops as the top soil structure deteriorates. Maintaining soil productivity of land of initially adequate structure and texture requires a proper balance of water held by the soil, and air admitted to plant roots, along with sufficient loose, porous soil to avoid restricting root growth. This is an old concept, and soil organic matter has long been used in the form of cover crops, composts, manures, peat products, spent mushroom soil, and various agricultural residues to accomplish the formation of water-stable aggregates from fine soil particles. Organic matter may perform its function by encouraging growth of fungi mycelium which wrap themselves around the soil particles, thus forming aggregates. Such aggregates prevent the formation of hard clods that slake down when exposed to water. The development of chemical soil aggregants is an attempt to prepare even more effective agents of higher concentration, uniformity and stability. It should be remembered, however, that natural organic materials leave beneficial effects aside from soil aggregation. Therefore, the much advertised figures showing that 100 to 1,000 lbs. of peat or compost can be replaced by 1 lb. of chemical soil conditioner are grossly misleading.

The use of a soil conditioner, then, may be indicated where there is a textural or structural deficiency. The extent to which soil conditioning chemicals can replace other natural agents used in the past has not been determined, nor is it known how long these chemicals will function or how they will ultimately affect crop productivity. The answers to these questions may require some little time.

(b) To control soil erosion: Controlling soil erosion usually requires careful annual maintenance of natural vegetation with grading, terracing and use of retaining walls where indicated. Wiry-rooted plants are especially helpful. The difficulty in controlling soil erosion often lies in providing adequate protection of the seed after sowing to insure that the roots take hold during early stages of growth. Cover straw is frequently used, held in place with light, open-weave fabrics or with strips of asphalt. Low raw material costs (straw @ $20 to $30 per acre) are offset by high labor and maintenance costs. Use of chemical soil conditioners may offer economic advantages despite higher raw material costs (about $300 per acre), since a one-shot technique is being developed to apply the seed, fertilizer and soil conditioner simultaneously. A deep treatment is not required, the soil conditioner

serving only to provide a water-permeable film over the surface of bare slopes to prevent wash-outs during early stages of vegetation growth.

(2) Industrial developments.

C. A. Thomas and C. A. Hochwalt of Monsanto, according to a Monsanto publication, in 1941 observed variation in corn production on land receiving presumably the same rainfall, fertilizer, cultivation, and crop rotation. Research was held in abeyance until after World War II, then Monsanto's Central Research Department in Dayton, Ohio, began their investigations under Hedrick, Mowry and Quastel. Different crop yields were obtained from soils containing same nutrients and trace elements. This led to their investigation of chemicals to improve the structure and texture of soils.

During the 1951 growing season, BPISAE, SCS, and OES investigated a number of experimental soil conditioning chemicals provided by Monsanto. Favorable results were obtained on saline and alkali soils in California, indicating good prospects for reclamation of these soils for successful crop production. Experiments were later conducted in other States, including Alabama, Tennessee, Mississippi, Ohio, Maryland, New Jersey, Pennsylvania and Wisconsin. Probably all the State Experiment Stations are working with chemical soil conditioners by now. Definite improvement in crop productivity in heavy clay soils has been established, believed to be the result of increasing the aeration necessary for normal root development.

Announced in December 1951, Monsanto's Krilium received such a response that a parade of chemical soil conditioners have since entered the scene. American Cyanamid's Aerotil line, understood to be based upon hydrolyzed acrylonitrile salts, seems to be offering the chief competition. Cyanamid, the largest producer of acrylonitrile, is distributing to a number of firms, including duPont, who package and market under their own trade names.

Both Krilium and Aerotil aggregate and loosely cement soil particles together to transform tight, gummy clays into friable materials of crumb-like structure, similar to good garden soil. Even though these agents must dissolve in the soil moisture to promote physical improvement, they apparently do not leach out or move below the zone of application. For that reason their potential effectiveness even at full plow depth may be somewhat limited by impervious sub-soil conditions.

Chemically, Krilium was announced originally as a sodium or calcium salt of a hydrolyzed polyacrylonitrile. However, Monsanto now seemingly uses the term more loosely as a trade name to designate their entire family of soil conditioning

chemicals. Therefore, all the "Kriliums" may not necessarily be closely related chemically. The Krilium now on the retail market is known as Monsanto's "Merloam" formulation and is understood to be based upon a vinyl acetate - maleic acid derivative. Monsanto claims to be independent of other manufacturers for their Merloam raw materials, which is not yet so in the case of the Krilium compounds based upon acrylonitrile. At least six experimental Krilium formulations are now being evaluated with the assistance of the Department of Agriculture. It should be noted that the Merloam formulation contains 75% clay to prevent caking, and proportionately more of this diluted product must be used than of certain other formulations under investigation containing higher amounts of active ingredients. This means 1 to 4 tons of Merloam per acre at six-inch depth to achieve the recommended 1/4 to 1 ton of 100% Krilium.

The following is quoted from recent newsletters circulated by BPISAE and is based upon their experience with Krilium to date. Our Bureau is now on the BPISAE mailing list to receive future announcements:

"The method of applying Krilium depends somewhat on whether the soil is moist or dry, and upon vegetation to be grown. Best results may be obtained when it is applied to a soil previously prepared for seeding. The dry powder should be spread uniformly and immediately incorporated to the desired depth by any method that gives thorough mixing of soil and conditioner. The soil must not be too wet for cultivation, and the surface must be fairly dry, to prevent gumming of the conditioner, which is very hygroscopic. Treatment of a moist soil may be improved by a second stirring not later than one day after treatment. If conditioner is applied to a dry soil, the soil should be subsequently wetted to at least the depth of treatment, in which case it may be preferable to seed before watering.

"Rates of application range from about 400 to 2,000 lbs. (of active ingredient) per acre when incorporated in soil to a 6-inch depth. Perhaps 1,000 pounds will constitute a representative rate when the material is uniformly incorporated with soil. The possibilities of widespread agricultural use, however, do not seem large, in view of . . . high prices.

"Attention is called, however, to a number of specialized agricultural uses for which the material should be suited and economic--preparation of potting soils, the greenhouse production of flowers and vegetables, the home flower and vegetable garden located on heavy, difficultly workable soil, and possible certain market garden areas where specialty crops are grown. For garden plots, Krilium should be mixed thoroughly to spade depth, using

a rate of about 0.1 percent or one pound to 20 square feet. In case of potting soil, one ounce should be well mixed with about 100 pounds of soil.

"Another field of possible economic utilization includes the stabilization of soil on road cuts and similar engineering projects. In such cases an application of one pound per 100 sq. ft. (about 400 pounds per acre) applied on the surface serves to hold the soil while turf is being established from seed. For erosion control, no stirring of soil is necessary after applying the conditioner.

"Additional research is planned by BPISAE and by various State Agricultural Experiment Stations. One of the items receiving attention in BPISAE is the treatment of a narrow band of soil above the seed or a shallow overall treatment for the purpose of improving germination. It is expected that reports giving definite comparative data will be made from time to time . . .

"Other soil conditioners are now commercially available. The Department of Agriculture does not have information on all of these compounds, but several soil conditioning materials are being included in current field tests . . . Some manufacturers indicate the nature of the chemical compounds that they use, while others do not. This means that in some cases readers of their literature have some basis for evaluating possible usefulness of the material, while in other cases they are left without fundamental information.

"Some of the materials offered for sale are in powder form consisting almost entirely of active ingredients. Other materials consist of active powders mixed with various quantities of inert substances. These inert materials may have some merit as a means of preventing caking of the organic compounds, which are frequently hygroscopic. Some products are in liquid form. With these, as well as with the dry aggregants, it is of great importance for the buyer to consider the amount of active ingredients purchased ...

"Purchasers of soil aggregate stabilizing chemicals should buy the products only with an experimental point of view at the present time. Soils vary in their response to these chemical treatments. Work to date indicates that these conditioners are most effective on soils with high clay and silt content. Soils which already have good structure naturally will not show great improvement. It is, therefore, suggested that only small quantities be purchased until the grower is convinced by experience that better soil conditions gained from their use are worth the cost involved."

Additional recently initiated large-scale experiments within Department or State agencies on commercially available soil conditioners include evaluations of tillage effects (Beltsville), water stability of soil aggregates (Auburn, Ala., and State College, Miss.), and efficiency in playground soils to prevent packing (Annapolis, Md.).

No evidence has been found (or claimed) that the chemical soil conditioners have fertilizer value, but it appears that through their useful effects plant nutrients of soils, as well as nutrients of fertilizers, do become more readily available to growing plants. Since the chemicals thus far involved are not believed to be new, it is my understanding that patent protection sought by Monsanto is based upon their development of a new use, and not new compounds.

It has been brought to our attention that the Northeast Wood Utilization Council and the Weyerhauser lumber interest have been active for years in attempting to develop means for using lignin residues as soil conditioners. Waste liquor from paper making yields 1-1/2 million tons of lignin annually. It has been brought to our attention also that two companies, each with a large financial backing, have actually entered the market with products prepared through controlled composting of organic residues. One, the Green-Grow Company, is marketing a product known as "Humex" prepared by composting cotton gin wastes. The other firm, Frazer Products, Inc., is producing a "Frazer Compost," source unknown. In addition to reviewing the literature on lignin research, it might be worthwhile to investigate the operation of Green-Grow and Frazer from the standpoint of determining whether BAIC research seems economically justified on derivatives other than those which are strictly soil aggregants.

(3) Problems visualized in establishing a stable mass market for chemical soil conditioners.

(a) The biggest barrier is one of price. The present investment of several thousand dollars per acre (at full plow depth) is judged far too costly, even with crops yielding high returns, considering that the life of treatment and long-term effects on crop yields are unknown.

(b) The size of a real sustaining market for soil conditioners is not yet known (to us), since information showing acreage of soils and crops which stand to gain has not been fully developed. The present boom is believed mainly in response to a new fad. Even if present prices were reduced 50%, it is expected that the available conditioners would probably settle down to usage in greenhouses, specialty farms and hobby gardens. Even these markets may diminish, since at least one of the products now

distributed in the East is regarded as worse than useless, and unfavorable reaction is believed sure to follow.

(c) One basic difficulty in encouraging sound soil conservation practices has been the farmers' attitude toward applying techniques which do not produce immediate results. As pointed out to me, the philosophy of a man working 14 hours a day in the field may not be conducive to encouraging research which may take 10-20 years to show results. As an example, many farmers instead of using straw as a cover crop sell their straw and then burn the field, knowing that excellent crops may result for 1-2 years even though eventually the land deteriorates. Soil conditioning chemicals which are effective may produce striking results in a year or two, which would seem to offset the importance of this agreement. However, there is a greater general need for fertilizers than for soil conditioners, and in spite of rapid results, fertilization is such an old subject it is difficult to arouse enthusiasm.

(d) Assuming lasting improvements in soil are gained through use of soil conditioning chemicals; assuming these improvements are at least equivalent to results obtainable through known sound farm practices, including crop rotation; it has been postulated that as a consequence it might become very difficult to encourage crop rotation. If so, a spread in crop diseases and insect infestation could follow, judging from past experiences in one-crop areas, as a result of local build-up of insects and disease organisms. Other thoughts on this subject have been less pessimistic. Since the value of crop rotation already has become established, the practice may well continue without interruption.

(4) Approaches for research on soil conditioners in BAIC.

It has been proposed that the Bureau consider undertaking a program of chemical modification of agricultural residues to produce low-cost soil stabilizing products. There are at least two approaches to this proposition: (a) development of inert, stable soil conditioning chemicals lower in cost than products now available, and (b) development of "compromise" products having both soil conditioning and fertilizing properties.

The soil research men I contacted suggested we concentrate on the first approach, even though our chances for success were not viewed optimistically unless those wastes can be successfully used which accumulate in large quantities and which offer the least problems in storage and transportation.

Sawdust and lignin were suggested as two of the most likely raw materials if within our authorization to work on them. Bagasse also was mentioned as a possibility since it is already to be found in locations which have much to gain through application of soil conditioners. Evidently sugar lands are among those which become depleted quite rapidly.

In spite of the recognized appeal of "natural vs. synthetic" soil conditioners, it was thought that we would have even less chance for success in research to utilize wastes as sources of products effective both as conditioners and plant foods. Residues already serve this function to a large extent without modification. Composted waste products which act more rapidly either can be purchased on the market or can be readily prepared on the farm. Also, a large variety of fertilizers and soil additives already are available at reasonable cost to supply specific soil needs. On the other hand, if our Bureau can develop or improve methods for the simple conversion of residues into more effective composts, this approach might be justified, especially if such methods are adaptable for use by small, local industries or by the farmer himself. A development such as this could make a good Farmers' Bulletin, if sufficient new information can be presented.

The problem of utilizing cellulosic materials to produce products both water-soluble and resistant to action of microorganisms in recognized as a difficult one. Drs. Rist, Russell, and Schniepp of NRRL, in their memoranda of February 1952 on the subject, have provided what seems to me to be a very sound and thorough analysis of the problem. While recognizing the economic and technical difficulties to be faced, they have suggested a number of reactions of possible interest which are noted below. Drs. Altschul, Fisher, Guthrie, Hopper, and Reid of SRRL and Drs. Porges and Morris of ERRL have furnished worthwhile suggestions also, which are likewise included.

<u>Suggestions for research to develop inert, stable soil conditioners lower in cost than products now available, or improved composts or hydrolyzable products to function both as fertilizers and conditioners from wastes, residues or chemicals derived from same.</u>

1. Polymerization and oxidation of furfural which, if successful, could be followed by direct processing of high pentosan materisls (NRRL).

2. Hydrolysis of methylfuran and polymerization of levulinaldehyde (NRRL).

3. Studies of lignins and lignin sulfonic acids to see if they can be successfully modified (NRRL).

4. Modifications of waste materials high in pectin, agar, or other polyuronides to increase their effectiveness (NRRL, SRRL).

5. Oxidation of corncobs or wheat straw (NRRL).

6. Polycyano and polyamide compounds, such as might be derived by reaction of cellulose with acrylonitrile and acrylamide, respectively, or related chemicals (SRRL).

7. Polycyano and related compounds, such as might be obtained through reaction of acrylonitrile with oil-seed meals (NRRL -- (soybean oil meal after protein extraction suggested by NRRL, but could apply to other meals as well).

8. Xanthation of cellulose-containing materials with possible post-treatment with formaldehyde (SRRL).

9. Phosphorylation of cellulose-containing materials to provide rot resistance and cation exchange properties (SRRL, NRRL).

10. Copolymers of vinyl acetate (or some other suitable monomer) with aconitic acid; itaconic acid; vinyl ether of lactic or citric acid; monovinyl ester of citric, anonitic, tartaric, pinic, and succinic acids (SRRL) -- (suggested by effectiveness of Monsanto's maleic acid - vinyl acetate Krilium compound).

11. Oxidation of starchy wastes by heterogenous reactions (with cheap reagents or by electrolytic reactions) to introduce both carboxyl groups for soil stabilization and blocking groups to resist microbial action (NRRL).

12. Modification of carboxyalkyl starch to resist bacterial action (NRRL).

13. Preparation of carboxylated chitin-like polymers (NRRL).

14. Treatment with propiolactone to give products containing both acid-ether and hydroxy-ester groups, possibly useful as such, or serving as intermediates for further reactions (SRRL).

15. Treatment of citrus pulp wastes with hot caustic, or oxidation (possibly with nitrogen oxides) to form polybasic acids (SRRL).

16. Develop improved composts by determining optimum conditions for controlled cellulose breakdown to form humus-like structures (NRRL, SRRL, ERRL) -- (rice hulls

have been considered by SRRL, specifically, but basic principles would apply also to other wastes. Louisiana State Experiment Station has been suggested by SRRL as possible contractor for this work).

17. Develop improved composts from cannery wastes through better sewage treatment, preferably extracting B_{12} from wastes beforehand (ERRL).

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